

Gluon dissociation of J/ψ in anisotropic *Quark-Gluon-Plasma*

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ABSTRACT

We calculate the gluon dissociation cross-section in an anisotropic quark gluon plasma expected to be formed in relativistic nucleus-nucleus collisions. It is shown that the thermally weighted cross-section of gluon dissociation undergoes modification in anisotropic plasma affecting the J/ψ survival probability. The dependence of the cross section on the direction of propagation of the charmonium with respect to the anisotropy axis is presented. Survival probability of J/ψ in two different space time models of anisotropic quark gluon plasma (AQGP) has been calculated. It is shown that depending upon the initial conditions (corresponding to RHIC energies), the survival probability in AQGP differs from that in isotropic QGP both in the central as well as forward rapidity regions. For initial conditions relevant for LHC energies, marginal difference between the the two space time models has been observed with a given initial conditions.

1 Introduction

Ever since the possibility of creating quark gluon plasma (QGP) in relativistic heavy ion collision was envisaged, numerous signals were proposed to probe the properties of such an exotic state of matter. In this context Satz and Matsui [1] had suggested that the production of heavy quark resonances (J/ψ) will be suppressed as a result of colour Debye screening in a hot and dense system of quarks, anti-quarks and gluons. This suppression could be detected experimentally through the dileptonic decay mode of these resonances. ALICE dimuon spectrometer [2] is dedicated to look for this type of signal. However, it is a daunting task to disentangle the contributions of the heavy quarkonium states to muon spectrum due to the background from several other sources, *e.g.* Drell-Yan, semileptonic decay of open heavy flavoured mesons ($D\bar{D}$, $B\bar{B}$) etc. Low energy muons from kaons and pions also constitute a large background.

In a QGP the much harder gluons can easily break up a J/ψ contrary to the case of hadronic system. In equilibrating plasma the gluons have much harder momentum sufficient to dissociate the charmonium. Such a study has been performed in Ref. [3] quite some time

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ago. Ever since the physical picture of quarkonium dissociation has undergone slight refinement during the couple of years. First of all, most of the existing calculations on various observables assume, from the very beginning, that the plasma is isotropic which may not necessarily be true as we shall argue in the following. Moreover, many properties of the QGP are still poorly understood. The measurement of elliptic flow parameter and its theoretical explanation suggest that the matter quickly comes into thermal equilibrium (with $\tau_{\text{therm}} < 1$ fm/c, where τ_{therm} is the time of thermalization) [4]. As for example, one of the major difficulty is to measure the thermalization (τ_{therm}) and isotropization (τ_{iso}) time of the QGP. On the one hand, the success of ideal hydrodynamic fits to experimental data [4] implies rapid thermalization of the bulk matter created at RHIC. On the contrary, perturbative estimation suggests relatively slower thermalization of QGP [5]. However, recent hydrodynamical studies [6] have shown that due to the poor knowledge of the initial conditions there is a sizable amount of uncertainty in the estimate of thermalization or isotropization time. It is suggested that (momentum) anisotropy driven plasma instabilities may speed up the process of isotropization [7], in that case one is allowed to use hydrodynamics for the evolution of the matter. However, instability-driven isotropization is not yet proved at RHIC and LHC energies.

In absence of a theoretical proof favoring the rapid thermalization and the uncertainties in the hydrodynamical fits of experimental data, it is very hard to assume hydrodynamical behavior of the system from the very beginning. The rapid expansion of the matter along the beam direction causes faster cooling in the longitudinal direction than in the transverse direction [5]. As a result, the system becomes anisotropic with $\langle p_L^2 \rangle \ll \langle p_T^2 \rangle$ in the local rest frame. At some later time when the effect of parton interaction rate overcomes the plasma expansion rate, the system returns to the isotropic state again and remains isotropic for the rest of the period. Therefore, it has been suggested to look for some observables which are sensitive to the early time after the collision. The effects of pre-equilibrium momentum anisotropy on various observables have been studied quite extensively over the past few years. Heavy quark energy loss and momentum broadening in anisotropic QGP have been studied in Refs. [8, 9]. Effects of anisotropy on photon and dilepton yields have been investigated rigorously in Ref. [10, 11, 12, 13, 14]. The effect of initial state momentum anisotropy on the radiative energy loss has been demonstrated in Ref. [15]. Recently, the authors in Ref. [16] calculated the nuclear modification factor for light hadrons assuming an anisotropic QGP and showed how the isotropization time can be extracted by comparing with the experimental data. Most importantly, the heavy quark potential has been calculated in Ref. [17] and the solutions of Schrodinger equations have been obtained in Ref. [18] corresponding to anisotropic system.

It is to be noted that the calculations of J/ψ dissociation cross-section in Ref. [3] have been performed in an equilibrating plasma and it is found that the survival probability increases in such system. We, in the present work, shall extend the above work assuming initial state momentum space anisotropy.

The plan of the paper is the following. In section 2 we briefly recall the necessary ingredients to calculate the thermally weighted gluon dissociation cross section in anisotropic media. Then we discuss how this can be implemented to calculate the survival probability of J/ψ along with space-time models for the anisotropic media. Section 3 will be devoted to discuss the results. Finally, we conclude in section 4.

2 Formalism

2.1 The thermal-averaged Gluon- J/ψ dissociation cross section

Peskin and Bhanot first calculated the quarkonium-hadron interaction cross section using operator product expansion [19]. Similar result was obtained using the QCD factorization theorem in Ref. [20]. Same formalism allows to express the hadron- J/ψ inelastic cross section in terms of the convolution of the inelastic gluon- J/ψ dissociation cross section with the gluon distribution inside the hadron. The perturbative prediction for gluon- J/ψ dissociation cross section is [21]

$$\sigma(q^0) = \frac{2\pi}{3} \left(\frac{32}{3}\right)^2 \left(\frac{16\pi}{3g_s^2}\right) \frac{1}{m_Q^2} \frac{(q^0/\epsilon_0 - 1)^{3/2}}{(q^0/\epsilon_0)^5}, \quad (1)$$

where q^0 the energy of the gluon in the stationary J/ψ frame; ϵ_0 is the binding energy of the J/ψ where $q_0 > \epsilon_0$. g_s is the coupling constant and m_Q is charm quark mass. A few comments about the binding energy of quarkonium states is in order here. It is to be noted that We have used the constant binding energy of the J/ψ in AQGP at finite temperature. However, using the real and imaginary part of heavy quark potential (calculated in anisotropic QGP) in Schrodinger equation the authors of Ref. [22] have shown that the binding energy of quarkonium states strongly depends on the anisotropy parameter as well as on the hard momentum scale. This observation might have important consequences on the gluon dissociation cross-section and hence on the survival probability.

we assume that the J/ψ moves with four-momentum P given by

$$P = (M_T \cosh y, 0, P_T, M_T \sinh y) \quad (2)$$

where $M_T = \sqrt{M_{J/\psi}^2 + P_T^2}$ is the J/ψ transverse mass and y is the rapidity of the J/ψ . A gluon with a four-momentum $K = (k^0, \mathbf{k})$ in the rest frame of the parton gas has energy $q^0 = K.u$ in the rest frame of the J/ψ . Now to calculate the velocity averaged cross section in anisotropic media we note that the anisotropy enters through the distribution function [12, 14],

$$f(k^0, \xi, p_{\text{hard}}) = \frac{1}{e^{k^0/p_{\text{hard}}} \sqrt{1 + \xi(\hat{k} \cdot \hat{n})^2} - 1} \quad (3)$$

where p_{hard} is the hard momentum scale, \hat{n} is the direction of anisotropy which is along the beam axis and the parameter ξ is the anisotropy parameter ($-1 < \xi < \infty$). p_{hard} is related to the average momentum in the partonic distribution function. In isotropic case, $\xi = 0$ and p_{hard} can be identified with the temperature. In such case the gluon- J/ψ dissociation cross section becomes [3],

$$\langle \sigma(K.u) v_{\text{rel}} \rangle_k = \frac{\int d^3k \sigma(K.u) v_{\text{rel}} f(k^0, \xi, p_{\text{hard}})}{\int d^3k f(k^0, \xi, p_{\text{hard}})} \quad (4)$$

where v_{rel} is the velocity between J/ψ and a gluon where,

$$v_{\text{rel}} = 1 - \frac{\mathbf{k} \cdot \mathbf{P}}{k^0 M_T \cosh y} \quad (5)$$

Change of variables ($K \leftrightarrow Q$) can be obtained by using Lorentz transformations:

$$k^0 = (q^0 E + q(\sin \theta_p \sin \theta_q \sin \phi_q + \cos \theta_p \cos \theta_q))/M_{J/\psi} \quad (6)$$

$$\mathbf{k} = \mathbf{q} + \frac{qE}{|\mathbf{P}|M_{J/\psi}}[(qM_T \cosh y - M_{J/\psi})(\sin \theta_p \sin \theta_q \sin \phi_q + \cos \theta_p \cos \theta_q) + |\mathbf{P}|]\mathbf{v}_{J/\psi} \quad (7)$$

where $\mathbf{v}_{J/\psi} = \mathbf{P}/E$, $P = (E, 0, |\mathbf{P}| \sin \theta_p, |\mathbf{P}| \cos \theta_p)$ and $\mathbf{q} = (q \sin \theta_q \cos \phi_q, q \sin \theta_q \sin \phi_q, q \cos \theta_q)$. In the rest frame of J/ψ , numerator of the Eq. (4) can be written as

$$\int d^3q \frac{M_{J/\psi}}{E} \sigma(q^0) f(k^0, \xi, p_{\text{hard}}), \quad (8)$$

while, the denominator of Eq. (4) can be written as [8]

$$\int d^3k f(k^0, \xi, p_{\text{hard}}) = \int d^3k f_{\text{iso}}(\sqrt{\mathbf{k}^2 + \xi(\mathbf{k} \cdot \hat{\mathbf{n}})^2}, p_{\text{hard}}) = \frac{1}{\sqrt{1 + \xi}} 8\pi \zeta(3) p_{\text{hard}}^3 \quad (9)$$

where $\zeta(3)$ is the Riemann zeta function. The maximum value of the gluon J/ψ dissociation cross section [21] is about 3 mb in the range $0.7 \leq q^0 \leq 1.7$ GeV. Therefore high-momentum gluons do not see the large object and simply passes through it. On the other hand, the low-momentum gluons cannot resolve the compact object and cannot raise the constituents to the continuum.

2.2 Survival probability of J/ψ in an anisotropic media

To calculate the survival probability of J/ψ in an anisotropic plasma we consider only longitudinal expansion of the matter. With the velocity averaged dissociation cross sections, the survival probability of the J/ψ in the deconfined quark-gluon plasma is of the following form [3],

$$S(P_T) = \frac{\int d^2r (R_A^2 - r^2) \exp[-\int_{\tau_i}^{\tau_{\text{max}}} d\tau n_g(\tau) < \sigma(K.u)v_{\text{rel}} >_k]}{\int d^2r (R_A^2 - r^2)} \quad (10)$$

The upper integration limit $\tau_{\text{max}} = \min(\tau_\psi, \tau_c)$ and τ_i is the QGP formation time. $n_g(\tau)$ is the gluon density at a given time τ . Now the J/ψ will travel a distance in the transverse direction with velocity $\mathbf{v}_{J/\psi}$:

$$d = -r \cos \phi + \sqrt{R_A^2 - r^2(1 - \cos^2 \phi)} \quad (11)$$

Here $\cos \phi = \hat{v}_{J/\psi} \cdot \hat{r}$. The time interval $\tau_\psi = M_T d / P_T$ is the time before J/ψ escapes from a gluon gas of transverse extension R_A . In the case of anisotropic QGP τ_c is determined by the condition : $p_{\text{hard}}(\tau = \tau_c) = T_c$ [23], where $T_c \sim 170 - 200$ MeV.

The modifications in Eq.(10) in anisotropic media come from the gluon density, $n_g(\tau)$ and the velocity weighted cross-section. The former is given by $n_g(\tau) = 16\zeta(3)p_{\text{hard}}^3(\tau)/[\pi^2\sqrt{1 + \xi(\tau)}]$ and the latter has been discussed in the previous section. The time evolution of ξ and p_{hard} is described in the next section.

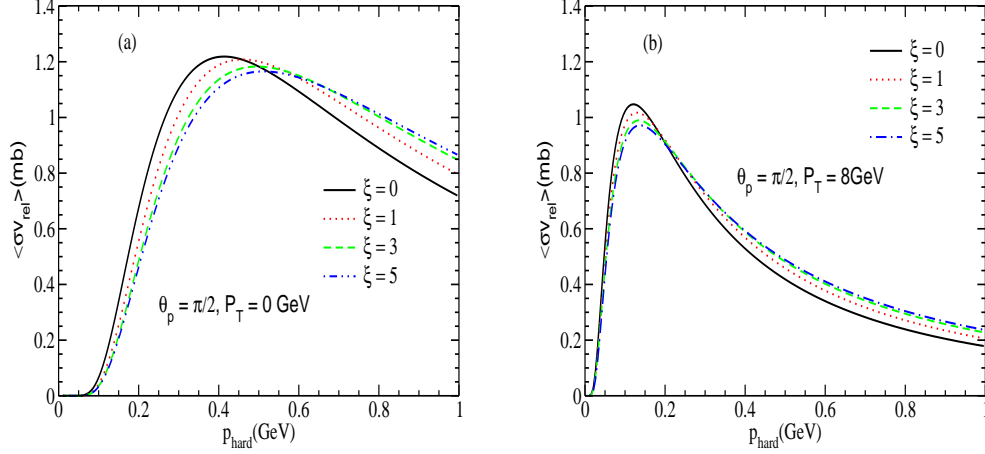


Figure 1: (Color online) The thermal-averaged gluon- J/ψ dissociation cross section as function of the hard momentum scale at central rapidity ($\theta_p = \pi/2$) for $\xi = \{0, 1, 3, 5\}$. (a) corresponds to $P_T = 0$ and (b) is for $P_T = 8$ GeV.

2.3 Space time evolution

2.3.1 Model I

For an expanding plasma the anisotropy parameter ξ and the hard momentum scale p_{hard} (appearing in Eq.(10)) are time dependent. Thus to calculate $S(P_T)$ one needs to know the time dependence of p_{hard} and ξ . To obtain the time evolution of the parameters we shall follow the work of Ref. [23, 24] and evaluate $S(P_T)$ of the J/ψ from the first few fermi of the plasma evolution.

The time dependence of relevant quantities is given by [23],

$$\begin{aligned} \xi(\tau, \delta) &= \left(\frac{\tau}{\tau_i} \right)^{\delta(1-\Lambda(\tau))} - 1, \\ p_{\text{hard}}(\tau) &= T_i \bar{\mathcal{U}}^{c_s^2}(\tau), \end{aligned} \quad (12)$$

where,

$$\begin{aligned} \mathcal{U}(\tau) &\equiv \left[\mathcal{R} \left(\left(\frac{\tau_{\text{iso}}}{\tau} \right)^\delta - 1 \right) \right]^{3\Lambda(\tau)/4} \left(\frac{\tau_{\text{iso}}}{\tau} \right)^{1-\delta(1-\Lambda(\tau))/2}, \\ \bar{\mathcal{U}} &\equiv \frac{\mathcal{U}(\tau)}{\mathcal{U}(\tau_i)}, \\ \mathcal{R}(x) &= \frac{1}{2} [1/(x+1) + \tan^{-1} \sqrt{x}/\sqrt{x}] \end{aligned} \quad (13)$$

where the exponent $\delta = 2$ corresponds to free-streaming pre-equilibrium momentum space anisotropy and $\delta = 0$ corresponds to thermal equilibrium, T_i is the initial temperature of the plasma and c_s^2 is the velocity of sound. $\Lambda(\tau) = \frac{1}{2}(\tanh[\gamma(\tau - \tau_{\text{iso}})/\tau_{\text{iso}}] + 1)$ is the smeared

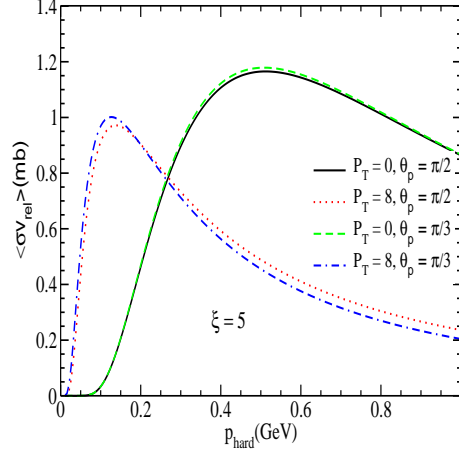


Figure 2: (Color online) Direction dependence of thermal averaged gluon- J/ψ dissociation cross section for two values of P_T and at two different rapidities.

step function introduced to take into account the smooth transition from non-zero value of δ to $\delta = 0$ at $\tau = \tau_{iso}$ [14] with γ being the transition width.

For isotropic case, we have $p_{hard} = T$, $\tau_{iso} = \tau_i$ so that $\Lambda = 1$, $\mathcal{U}(\tau) = \tau_i/\tau$, and $\mathcal{U}(\tau_i) = 1$. By using $c_s^2 = 1/3$ we recover the Bjorken cooling law [25]. As the colliding nuclei do have a transverse density profile, we assume that the initial temperature profile is given by [26]

$$T_i(r) = T_i \left[2 \left(1 - r^2/R_A^2 \right) \right]^{1/4} \quad (14)$$

Using Eqs.(12) and (14) we obtain the profile of the hard momentum scale as

$$p_{hard}(\tau, r) = T_i \left[2 \left(1 - r^2/R_A^2 \right) \right]^{1/4} \bar{\mathcal{U}}^{c_s^2}(\tau) \quad (15)$$

We use two sets of initial conditions for RHIC energies. The first set, henceforth referred to as Set I, corresponds to that used in Ref. [3], i.e., $T_i = 550$ MeV and $\tau_i = 0.7$ fm/c. For other set (set II) the initial temperature (time) has been calculated using the measured multiplicities at RHIC energies [16] and is given by $T_i = 440$ MeV corresponding to $\tau_i = 0.15$ fm/c. At LHC energies we use the initial conditions: $T_i = 820$ MeV and $\tau_i = 0.5$ fm/c.

2.3.2 Model II

The other alternative scenario of time dependence for ξ and p_{hard} in highly anisotropic system has been described in [27] taking the first two moments of Boltzmann equation which reads in (0+1)-dimension as

$$E \frac{\partial f(t, z, \mathbf{p})}{\partial t} + p_z \frac{\partial f(t, z, \mathbf{p})}{\partial z} = -C[f(t, z, \mathbf{p})] \quad (16)$$

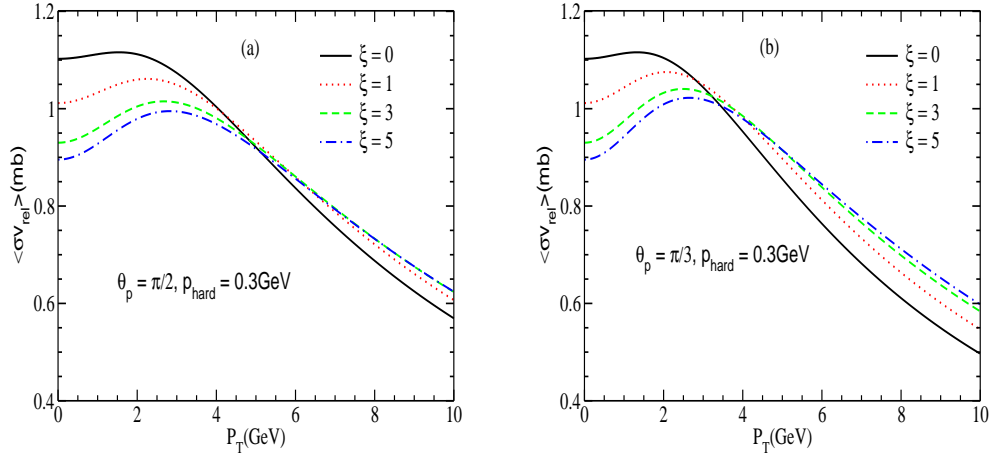


Figure 3: (Color online) The thermal-averaged gluon- J/ψ dissociation cross section as a function of the transverse momentum P_T for p_{hard} at (a) central and (b) forward rapidity regions.

Without going into further details we simply quote the coupled differential equations that has to be solved to get the time dependence of ξ and p_{hard} [27]:

$$\frac{1}{1+\xi} \partial_\tau \xi = \frac{2}{\tau} - 4\Gamma \mathcal{R}(\xi) \frac{\mathcal{R}^{3/4} \sqrt{1+\xi} - 1}{2\mathcal{R}(\xi) + 3(1+\xi)\mathcal{R}'(\xi)} \quad (17)$$

$$\frac{1}{1+\xi} \frac{1}{p_{\text{hard}}} \partial_\tau p_{\text{hard}} = \Gamma \mathcal{R}'(\xi) \frac{\mathcal{R}^{3/4} \sqrt{1+\xi} - 1}{2\mathcal{R}(\xi) + 3(1+\xi)\mathcal{R}'(\xi)} \quad (18)$$

where $\Gamma = 2T(\tau)/(5\bar{\eta})$ and $\bar{\eta} = \eta/s$, η is the shear viscosity co-efficient. In this model the time τ_c has been calculated using the relation $\mathcal{R}^{1/4}(\xi) p_{\text{hard}} = T_c$. We have used the same transverse profile for the hard momentum scale as in model I. A comparative study of the survival probability using the above described space-time models will be done.

3 Results

Let us first discuss the thermal averaged gluon dissociation cross section in anisotropic system. Eqs.(4)-(9) have been used for this purpose. The results are displayed in Fig. (1). Fig.(1a) and Fig.(1b) correspond to $P_T=0$ and $P_T=8$ GeV respectively for a set of values of the anisotropy parameter. It is seen that the cross section decreases with ξ for p_{hard} up to ~ 500 MeV and then increases as compared to the isotropic case ($\xi = 0$)(see in Fig.(1a)). Similar feature has been observed in Fig.(1b) for higher P_T where the cross section starts to increase beyond $p_{\text{hard}} \sim 200$ MeV.

As mentioned before, the dissociation cross section depends on the direction of propagation (θ_p) of the quarkonium with respect to the anisotropy axis. This dependence is shown in Fig. (2). We find marginal dependence in this case. These observations will have important consequences while calculating the survival probability (see later).

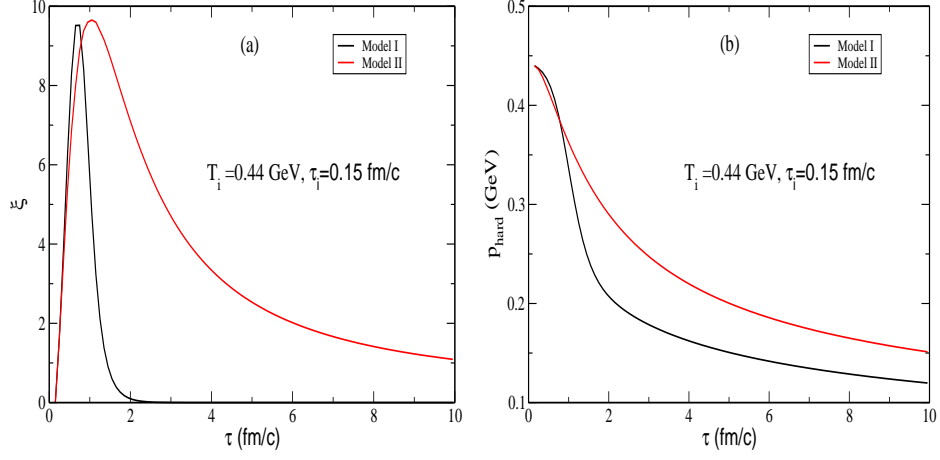


Figure 4: (Color online) Time evolutions of (a) the anisotropy parameter ξ and (b) the hard momentum scale p_{hard} in the two space time models described in the text.

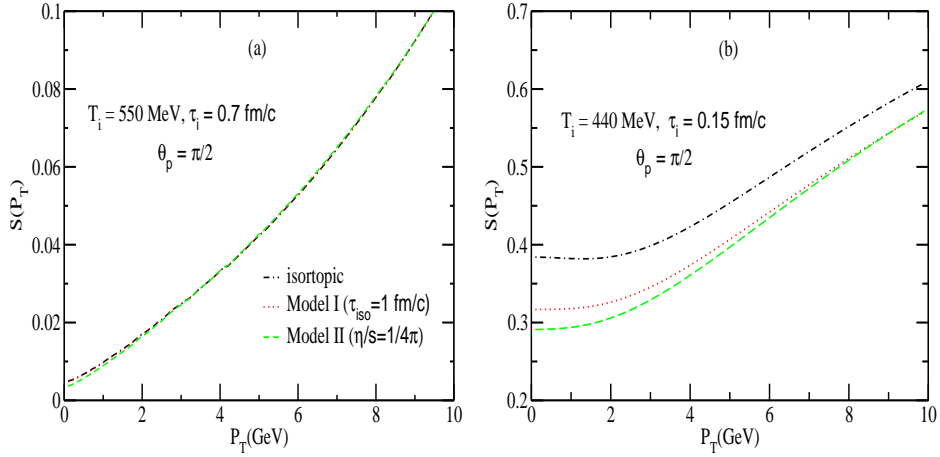


Figure 5: (Color online) The survival probability of J/ψ in an anisotropic plasma at central rapidity. (a) corresponds to $T_i = 550$ MeV, $\tau_i = 0.7$ fm/c and (b) is for $T_i = 440$ MeV, $\tau_i = 0.15$ fm/c.

In order to show the transverse momentum dependence for fixed hard momentum scale, we, in Fig. (3), present the dissociation cross section as a function of P_T of the J/ψ for $p_{\text{hard}} = 300$ MeV and for two values of θ_p . Again it is seen that the cross section first decreases with the anisotropy parameter upto $P_T \sim 5(3)$ GeV for $\theta_p = \pi/2(\pi/3)$ and we find larger increase away from the central rapidity region. This behavior might influence the survival probability which we consider next.

Before calculating the survival probability let us examine the time evolutions of ξ and p_{hard} in the space time models described earlier. This is needed to calculate the survival probability in an expanding plasma. The results are shown in Fig. (4). It is seen that the anisotropy parameter falls much rapidly compared to the case when model II is used (see Fig.(4a)). There is a narrow window in τ where ξ dominates in case of model I. The cooling is slower in case of model II as can be seen from Fig.(4b). These observations have important consequence on the survival probability as we shall see.

Eq.(10) has been used to calculate the survival probability. For the space time model I we use Eq.(14) and for model II Eqs.(19) and (20) have been used for the time evolution of the anisotropy parameter ξ and the hard momentum scale p_{hard} . Fig.(5) describes the survival probability for two different set (Set I and Set II) of initial conditions for a given direction of propagation of the J/ψ with the anisotropy axis. For the Set I initial conditions, the results are same for the isotropic case and the two space time models used for the anisotropic media (see in Fig.(5a)). However, for the Set II initial conditions and for the same θ_p , the results are different from each other as can be seen from Fig.(5b). More interestingly, we find an order of magnitude increase in the survival probability for the Set II initial conditions. This is because of the argument of the exponential in Eq.(10).

Next we consider the survival probability in forward rapidity region for the two sets of initial conditions and two space time models and compare it with that in the central rapidity region. Fig.(6a)((6b)) shows the survival probability calculated using Set I (Set II) initial conditions. It is seen that for the Set I initial conditions, $S(p_T)$, in the forward rapidity region is marginally larger than the case when space time model II is used. It is seen from Fig.(6b) that for Set II initial conditions, $S(p_T)$ is marginally higher in the case of space time model I in the low p_T region at central rapidity. However, at forward rapidity, the survival probability is always larger in case of space time model I.

In order to show the dependences of $S(p_T)$ on τ_{iso} in the space time model I and on η/s in space time model II we plot the survival probability for set I initial conditions in Fig.(7). It is observed that increasing τ_{iso} lowers $S(p_T)$ while increasing η/s enhances the survival probability.

The results for the LHC energies for the two sets of space time models are shown in Fig. (8). In case of central rapidity region we do not find any difference in the results for the two space time models. But the results are marginally different in case of forward rapidity region. However, in the forward rapidity region we observe that the survival probability increases by a factor of 2 compared to the case of central rapidity for a given set of initial conditions.

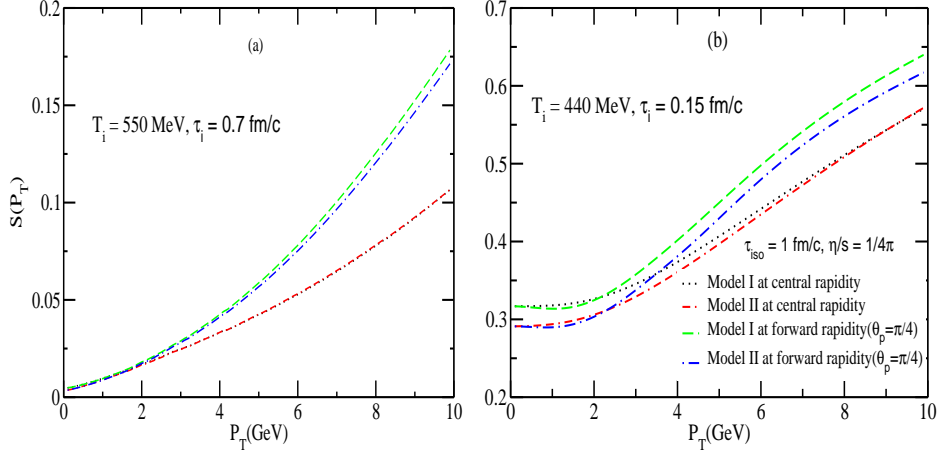


Figure 6: (Color online) The survival probability of J/ψ in an anisotropic plasma at central and forward rapidity regions corresponding to (a) $T_i=550\text{MeV}$, $\tau_i=0.7\text{ fm/c}$ and (b) $T_i=440\text{ MeV}$, $\tau_i=0.15\text{fm/c}$.

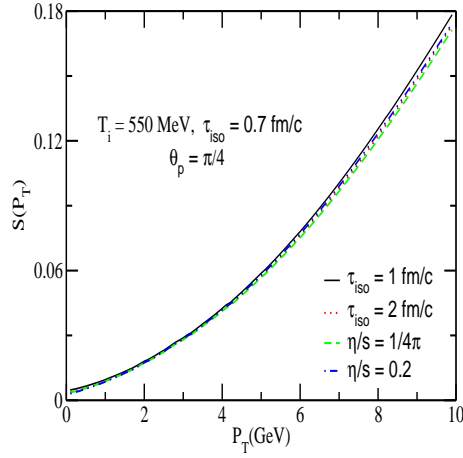


Figure 7: (Color online) The survival probability of J/ψ in an anisotropic plasma for two different model at same initial temperature $T_i = 500\text{ MeV}$ and initial time $\tau_i = 0.7\text{ fm/c}$ for different τ_{iso} and η/s .

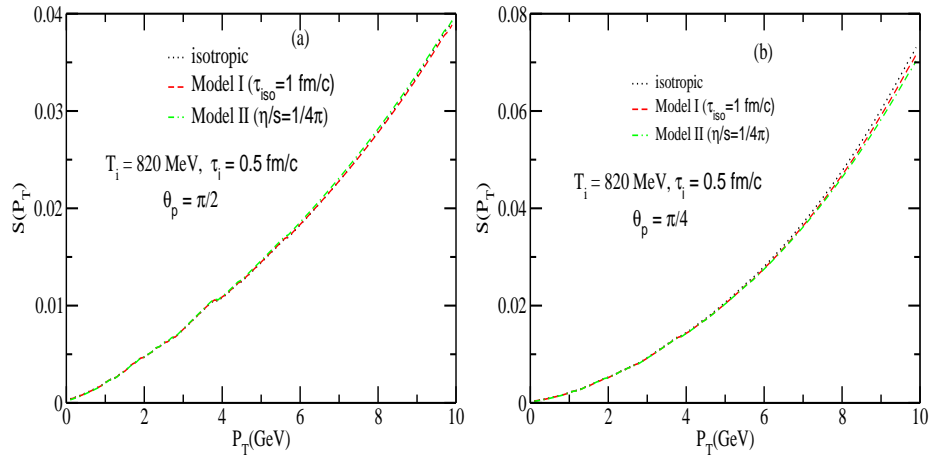


Figure 8: (Color online) The survival probability of J/ψ in an anisotropic plasma for (a) central and (b) forward rapidity region. The initial conditions are taken $T_i = 820$ Mev and $\tau_i = 0.5$ fm/c.

4 Summary

We have calculated gluon- J/ψ dissociation cross section assuming pre-equilibrium momentum space anisotropy in the deconfined phase expected to be produced in relativistic heavy ion collisions. It is observed that the thermally weighted cross section is modified substantially in anisotropic plasma. To calculate the survival probability of the J/ψ two sets of initial conditions and two different space models have been used both for RHIC and LHC energies. For set I initial conditions, in the central rapidity region we do not find any difference in the survival probabilities calculated in the isotropic and anisotropic QGP at RHIC energies. However, changing the initial conditions, it is seen that the survival probability is lower in AQGP. Moreover, there is noticeable difference in the results obtained using different space time models. We also show that the results for the survival probability depend on the isotropization time (in model I) and η/s (in model II). For the case of LHC with a given initial conditions the results marginally differ from each other in the forward rapidity region when two different space time models are used. It is also found that the results are not much sensitive to the direction of propagation of the J/ψ with respect to the anisotropy axis. It is also demonstrated that the results are extremely sensitive to the initial conditions, in particular, to the choice of the initial time. It is important to note that uncertainty may result from our assumption of chemical equilibrium. However, one can naively expect that finite chemical potentials should affect isotropic and anisotropic plasmas equally. So one expects that although the total yields could change, one would still see a sensitivity to the assumed isotropization or thermalization time. At leading order in the quark fugacity, the ratio of the isotropic to anisotropic result should be independent of the fugacity [28, 29]. We would also like to add that the consideration of transverse expansion may alter the results during the late stages of the collisions as has been observed in case of photon and dilepton transverse momentum distribution. However, transverse expansion is pronounced in the later stage

and its effect in the very early stage is minimal. Since in our case momentum anisotropy is an early stage phenomena, the effect will be negligible. We also note that treating the quarkonium binding energy as function of ξ and p_{hard} might alter the present findings and this is worth investigating.

It is to be noted that apart from this mechanism of suppression, there are other mechanisms by which J/ψ can be suppressed [3]. All these possible processes should be taken into account and then be compared with the experimental data of transverse momentum distribution of J/ψ to extract the isotropization time τ_{iso} as has been done in case of photons [12] and nuclear modification of light hadrons [16].

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